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WADC TECHNICAL REPORT 52-46

AN INVESTIGATION OF THE PROBLEM OF ICE REMOVAL FROM B-29 RADOMES

HARRY G. LAKE, CAPTAIN, USAF
COMPONENTS AND SYSTEMS LABORATORY

JANUARY 1952

WRIGHT AIR DEVELOPMENT CENTER

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AN INVESTIGATION OF THE PROBLEM OF ICE REMOVAL FROM B-29 RADOMES

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January 1952

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Wright Air Development Center
Air Research and Development Command
United States Air Force
Wright-Patterson Air Force Base, Ohio

McGregor & Werner, Inc., Wakefield, Mass.
May 12, 1952 150

FOREWORD

This report was initiated by Components and Systems Laboratory, Weapons Components Division, at the request of the Strategic Air Command. Work was accomplished under Research and Development Order No.R112-12, "Radomes, Aircraft and Guided Missiles." Captain H.G. Lake was project engineer. The entire program was planned, developed, and accomplished at Wright Air Development Center. The rubber deicer boot used in this program was procured from the B.F. Goodrich Co. under Purchase Order AF (33-601) 52-3535-W.

ABSTRACT

This report disseminates information on the problems of removing ice or preventing its formation on B-29 radomes. Each system described herein was investigated for its effectiveness as a means of deicing and for its effect on electrical transmission of radar equipment.

Three possible solutions are presented: the use of chemical coatings; fluid spray deicing; and the rubber deicer boot. The advantages and disadvantages of each system are discussed.

The tests which were conducted indicated that the systems developed and presented were adequate. However, it should be understood that these systems are but temporary solutions and work will continue until better methods can be evolved.

PUBLICATION REVIEW

The publication of this report does not constitute approval by the Air Force of the findings contained therein. It is published only for the exchange and stimulation of ideas.

FOR THE COMMANDING GENERAL:

for GORDON A. BLAKE
Brigadier General, USAF
Chief, Weapons Components Division

CONTENTS

ILLUSTRATIONS

SECTION I

INTRODUCTION

Following reports from the Strategic Air Command of radar failure because of radome icing, Components and Systems Laboratory was assigned prime responsibility for the development of an adequate and satisfactory method of preventing or eliminating ice formations on B-29 radomes. On 21 August 1951, Components and Systems Laboratory began the work which, it was hoped, would solve a problem which had long plagued the U. S. Air Force in its world-wide operation.

The requirement placed on Components and Systems Laboratory was for an immediate, interim solution until such time as more adequate anti-icing methods could be finally developed.

Because of the urgency of the problem, a three-month period was granted within which to provide a method for overcoming the problem of B-29 radome icing. It was expected that the solution would obviate the icing problem to the point where flight would not be hazardous but would cause a slight sacrifice of electrical accuracy and range.

Various studies relating to the basic problem of radome icing have been made by several commercial groups and Government agencies. Although much of the work accomplished was in connection with fighter-type aircraft, the approach was rather basic in scope. After reading the reports of these studies (see Bibliography) and discussing possible methods with engineers associated with anti-icing problems, it was decided to consider and investigate the following three methods: chemical coatings; fluid spray systems; and rubber deicer boots.

It should be recognized at the outset that each of these approaches has been attempted with varying degrees of success and has resulted in differing opinions. Therefore, although not new in theory, each of the three methods was evaluated to determine which would be most suitable as an interim solution to the B-29 radome icing problem.

SECTION II

CHEMICAL COATINGS

Objective.

The purpose of these tests was to determine both the effectiveness of various selected chemical coatings as anti-icing agents and their affinity to radome surfaces in flight and under varying atmospheric conditions.

Procedure.

To evaluate various chemical coatings as anti-icing agents, preliminary tests were conducted in a cold chamber. These tests were nonconclusive and were intended only as a guide to actual flight conditions. The following chemicals were used:

1. Silicone oil, DC 200, 100,000 centistokes, 20% solution in naphtha
2. Silicone oil, DC XF-126, 5% lead solids in Skelly Solvent H
3. Teflon grease (Polytetrafluoroethylene)
4. Glycerin mixed with Teflon grease

In each case, the chemical was applied to a polyester glass-fiber radome panel and also to a Neoprene-coated polyester glass-fiber radome panel. Each panel was coated completely and an uncoated panel was used as control in each test. In addition, a solid Teflon panel was tested. The panels were placed in a cold chamber at -20°F and sprayed with ice water. After a 10-minute exposure, removal of the resulting ice drops was attempted by scraping with the fingernail and also by a blast of compressed air at a pressure of about 50 psi with an ordinary shop-type nozzle. No test was repeated on any one chemical coating.

Results.

The following results were observed:

1. Ice adhered tightly to both the Teflon panel and to the panel coated with Teflon grease. The ice could not be removed either with the fingernail or by a blast of air.

2. Ice could be removed with the fingernail from the panels coated with the mixture of glycerin and Teflon grease but could not be removed by a blast of air.

3. Ice was removed easily from the panels coated with DC 200 silicone oil both with the fingernail and by air blast.

4. The best results were obtained from the panels coated with DC XF-126. The ice was easily removed by the air blast.

Although the polyester panels showed slightly less ice adhesion than did the Neoprene-coated panels, there was very little difference. It should be noted that the removal of ice by air blast may have been facilitated by the relatively high temperature of the compressed air.

The tests were repeated at temperatures as low as -40°F during which undiluted DC 200 in viscosities of 100,000 and 1,000,000 centistokes was used. The results were about the same as those obtained during the first tests.

Flight Test.

To determine the retainability of silicone oil under atmospheric conditions, a 20% solution of DC 200, used in previous cold chamber tests, was applied to the forward part of a radome which was mounted on a B-29. After several hours of flight, only a small amount of the oil was washed away by the air stream; much of the oil remained on the surface. The oil film did, however, collect some dirt particles which could easily act as nuclei for ice formation.

SECTION III

FLUID SPRAY DEICING SYSTEM

Objective.

The immediate problem was to develop a practical system which would provide an adequate spray coverage over the critical area of the radome.

Procedure.

In developing a fluid deicing system, it was first necessary to determine the following: (1) type of nozzle; (2) number of nozzles; (3) location of nozzles; (4) rate of flow; (5) line pressure.

From previous reports submitted by the various contractors who had tested fluid systems, first approximations could be made as to conditions needed for the system. Consequently, it was decided to use the following parts in the tests:

1. Radome, AF Dwg. No. 45G3025

2. Pump, Fluid Metering, AF Stock No. 4801-8817-1

3. Tank Assembly, Prop Deicer, AF Stock No. 0105-5105650

4. Tubing, Aluminum, 1/4-inch ID

5. Gage, Hydraulic, AF Stock No. 1800-338940

6. Solenoid Valves

Preliminary tests were run in a 20-foot wind tunnel to establish a suitable spray pattern. The radome used was mounted on a wooden platform and installed in the tunnel. Although the radome was thus in an inverted position, it was considered that there would not be sufficient difference to cause errors of any magnitude.

A 60% solution of ethylene glycol in water colored with methyl violet dye was used as the deicing fluid. Aerosol was used as a wetting agent to relieve surface tension. Alcohol was eliminated as a possible deicing fluid because of its high evaporation rate. The tests were run at an air speed of 200 mph.

After many changes and adjustments, it was finally decided that two nozzles placed 10 inches in front of the radome offered the best results. As shown in figure 1, the horizontal nozzle pointed directly to the rear, parallel to the axis of the radome, and the vertical nozzle sprayed perpendicular to the radome axis of symmetry. The horizontal nozzle had a flow rate of three gallons per hour with a 60° cone angle. The vertical nozzle was rated at six gallons per hour with a 30° cone angle. The spray pattern obtained was considered to be adequate to assure proper deicing. The next step was to prove the spray system in actual flight.

Flight Tests.

The fluid spray system, which had been tested in the wind tunnel, was installed on a B-29 (YKB-29J, Serial No. 44-27349). The two nozzles were installed 10 inches in front of the radome (same type as that used for wind tunnel tests of fluid spray system) with the tip of the lower nozzle three inches below the fuselage surface. A 1/4-inch aluminum line was routed from the nozzle bar to the forward crew compartment along the port side of the bomb bay. The tubing was connected to the equipment which was located on the flight deck between the radio operator and navigator stations. (See Fig. 2).

The test equipment consisted of two tanks, a pump, filter, two solenoid valves, pressure gage, nozzles, and switch panel (see Fig. 3).

A type A-4 35mm movie camera was mounted on the flare tube opening (Fig.4).

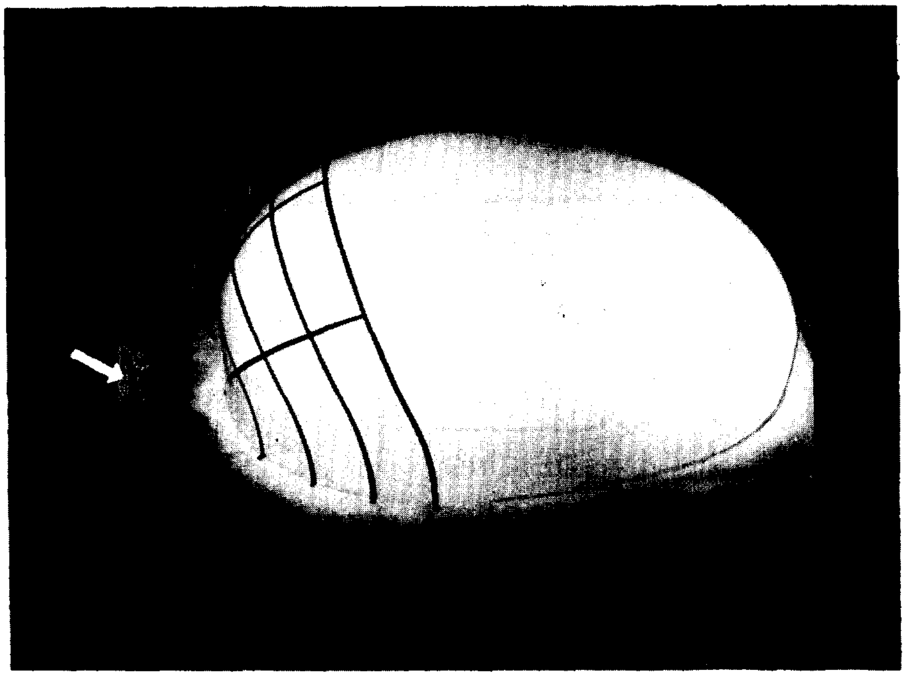

Fig. 1. Installation of Radome in 20-foot Wind Tunnel

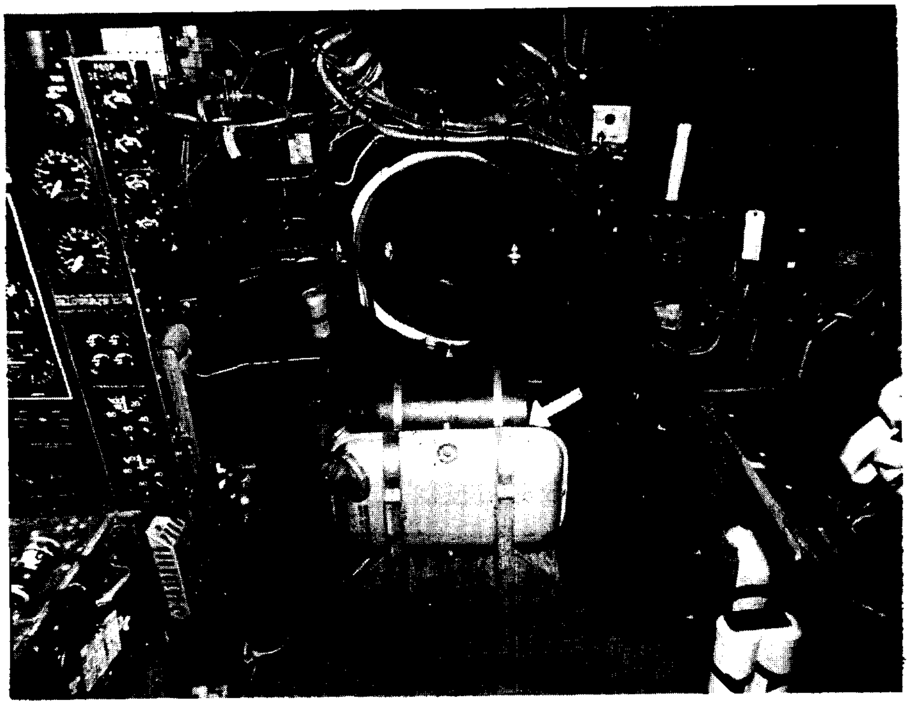

Fig. 2. Location of Deicing Equipment In Forward Pressurized Compartment

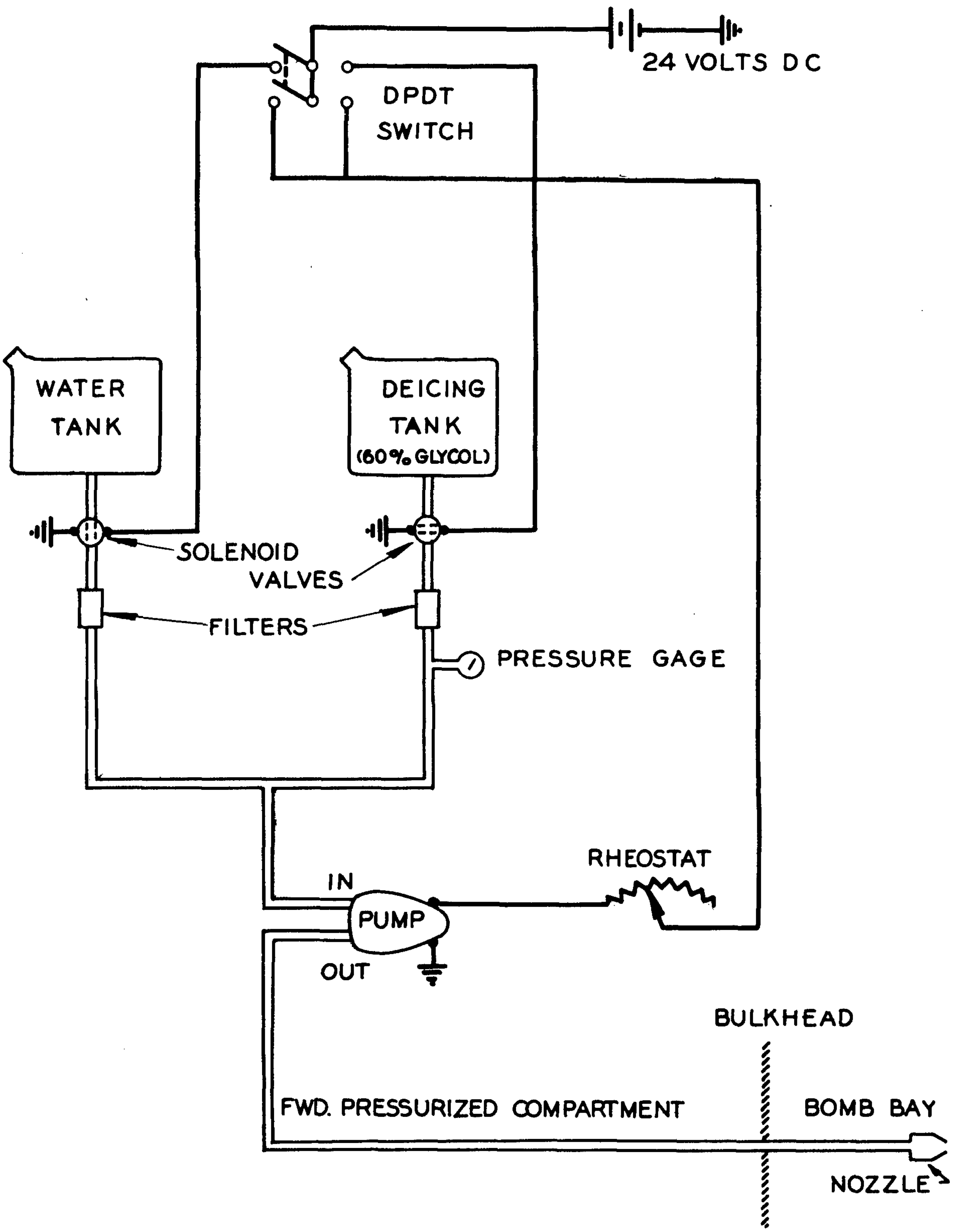

FIG. 3. SCHEMATIC - LIQUID DEICING SYSTEM - B-29 RADOME

To reflect the radome into the camera lens, a mirror was fitted at the outlet of the flare tube at approximately a 45° angle (Fig. 5). The switch panel was mounted on the navigator's table as shown in figure 6.

To aid in photographing the radome and to help in determining the extent of both the icing coverage and the spray pattern, the radome was painted light gray and then divided into sections by painted black lines (Fig. 7).

Tests were conducted to accomplish the following objectives: determine the deicing fluid spray pattern; simulate icing conditions and attempt deicing; check ethylene glycol as an anti-icing agent; and determine effects of glycol on radar attenuation.

Results:

The spray pattern can be varied depending on the rate of flow, cone angle of the nozzles, and line pressure of the system. Figures 8 and 9 show the radome adequately covered and virtually inundated.

Ethylene glycol proved successful as a deicing agent. A flow rate of 8-12 gph is sufficient to enable complete deicing, depending on the severity of the ice formation.

Ethylene glycol is not effective as an anti-icing agent. Ice will form on a radome surface which has been wet with glycol. It must, therefore, be concluded that glycol could be used most effectively as a freezing-point depressant after ice has begun to form.

Visual observation showed no degradation of picture, and radar transmission was normal during a deicing cycle. Comparisons of the radar scope were made with the deicing system in operation against a clear radome, and no difference in clarity or range could be noted.

IV

RUBBER DEICER BOOT

Objective.

The primary objective of the work relative to the development and use of a rubber deicer boot which would fit the B-29 radome was to determine whether or not the use of such a boot would affect the proper functioning of radar equipment installed on the B-29.

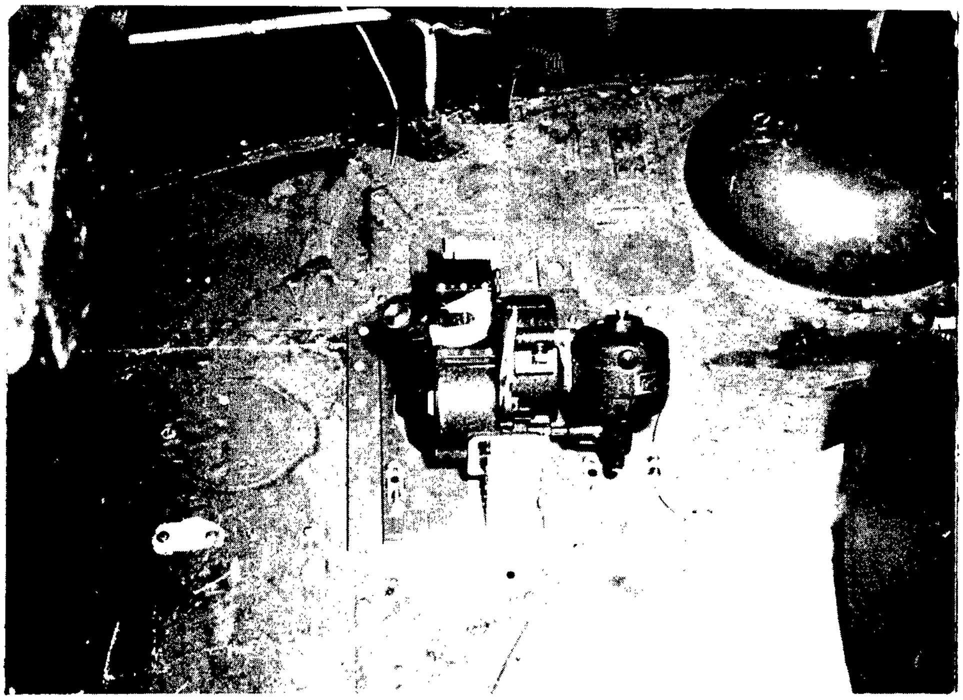

Fig. 4. Installation of Type A-4 Camera at Flare Tube Opening

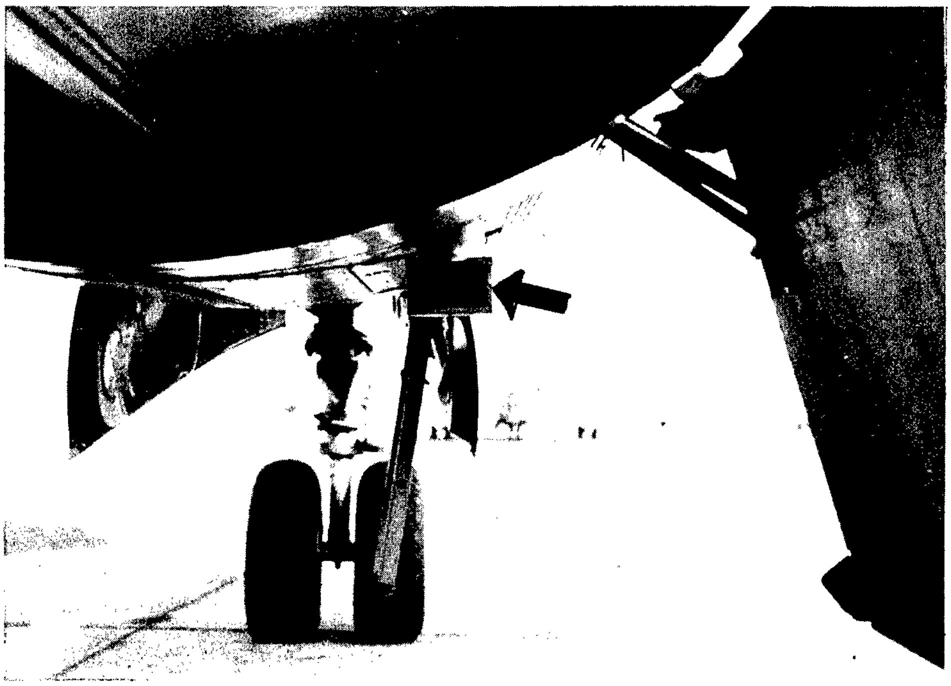

Fig. 5. Reflecting Mirror Located Forward of Front Bomb-Bay.

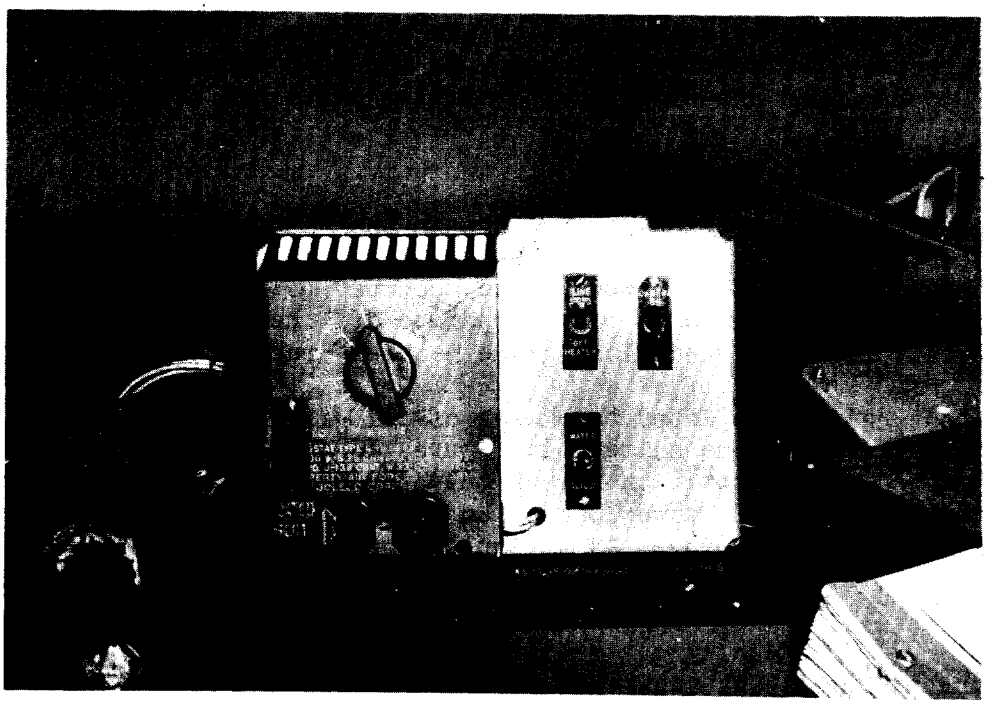

Fig. 6. Deicing System Switch Panel Located on Navigator's Table

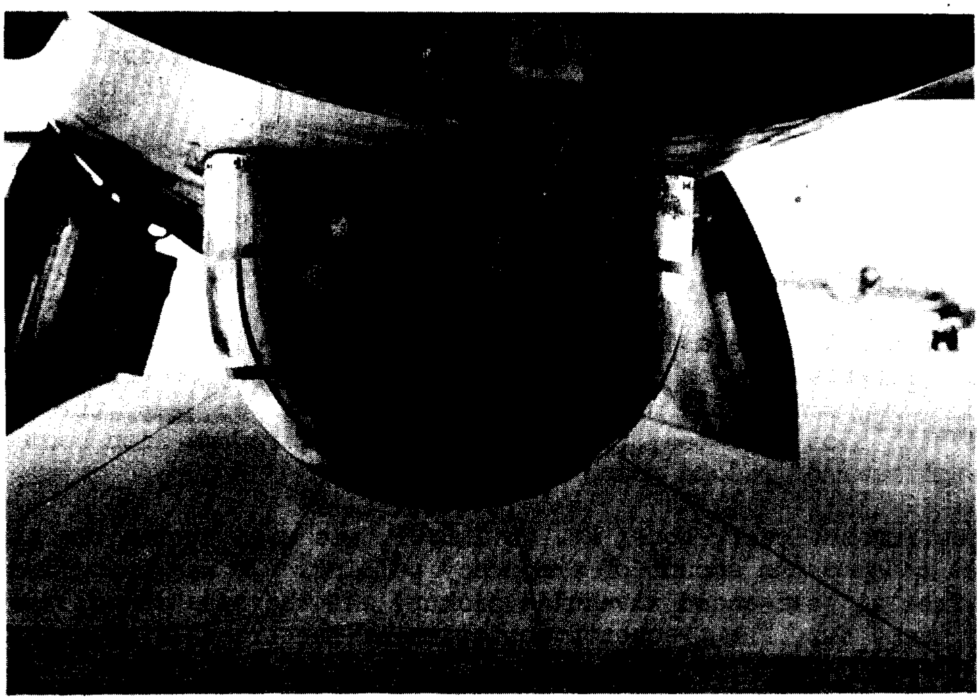

Fig. 7. B-29 Radome No. 45G3025 Located between Bomb-Bays

An effort was made to determine the degree of interference which would be imposed by the rubber deicer boot on the electrical transmission of the radar equipment. The deicing efficiency of the boot was actually not in question because past experiments with similar boots had been successful.

Procedure.

Because of their previous experience in the manufacture of rubber deicer boots, the B. F. Goodrich Company of Akron, Ohio, was requested to design and make a boot to fit the B-29 radome. The boot was to be of the rubber, pulsating, pneumatic type, and it was to operate off the wing deicer pressure-suction line. Low-loss electrical grade Neoprene rubber was used.

The boot, with a deflated thickness of .110-inch, was cemented to the forward part of the radome as seen in figures 10 and 11. A 5/8-inch aluminum tube was routed from a position immediately forward of the boot to the "B" port of the 2-1 solenoid valve located on the port side of the fuselage near the leading edge of the wing. As a result, the boot pulsated on the same frequency cycle as did the wing deicer boots.

Flight Tests.

Three tests were flown in an attempt to measure the degree of radar degradation. The flights were made between Wright-Patterson Air Force Base and Sidney, Ohio, and several runs were made during each test. The .110-inch boot was tested in each case.

The tests were flown at an altitude of 10,000 feet. Sidney was selected as a target since it appeared somewhere near full range for continuous mapping when viewed from a recognizable reference point which was, in this case, the Wright-Patterson range station.

A head-on approach to the target was made passing over the reference point. Pictures were taken of the radar scope at range settings of 5, 10, 20, 50, and 100 miles. The pictures were taken with the boot in a deflated and in an inflated condition.

Runs were also made using Sidney as a reference point and with Wright-Patterson Air Force Base as the target. In this manner, comparisons could be made among three conditions of transmission performance: (1) through front of radome with boot deflated; (2) through front of radome with boot inflated; (3) through rear of radome which was bare.

A spectrum analyzer, Model No. TS 148/UP, was used during one of the flights to measure the amount of frequency pulling. It was installed and operated from an open-ended waveguide pickup, and the spectrum of the radar pulse was tuned in. The frequency deviation of the transmitted signal was observed then and measured during normal scanning of the antenna at various tilt settings. Further plots were made of the frequency versus scan angle at various tilts under static conditions of scanning.

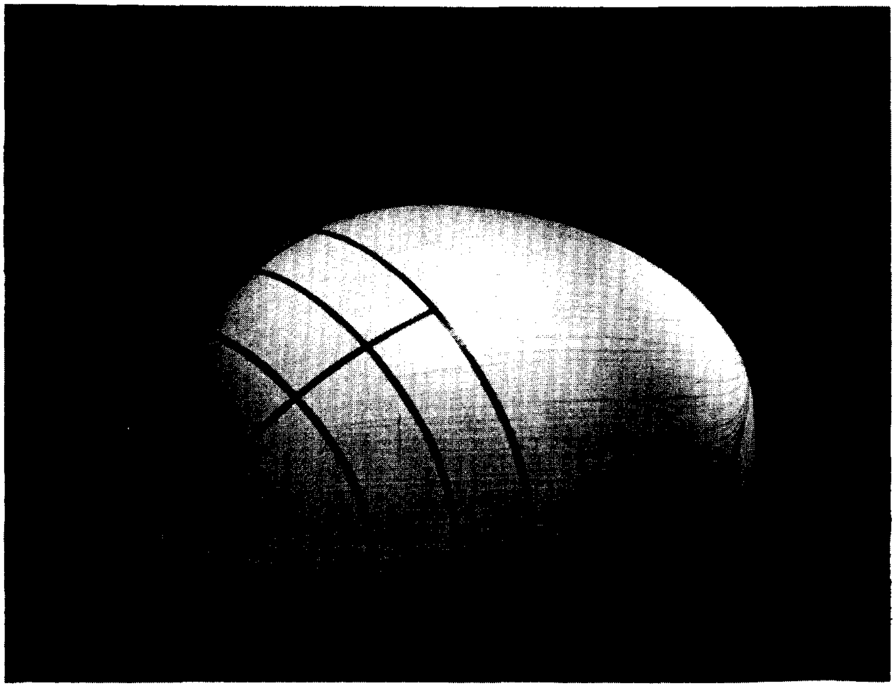

Fig. 8. B-29 Radome Showing Adequate Fluid Spray Coverage

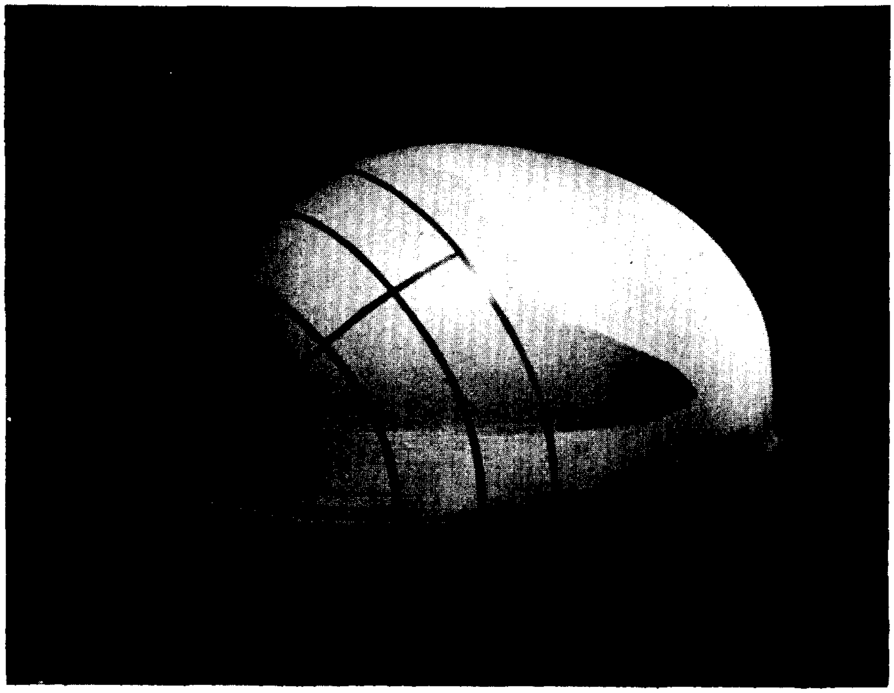

Fig. 9. B-29 Radome Showing Heavy Fluid Spray Coverage

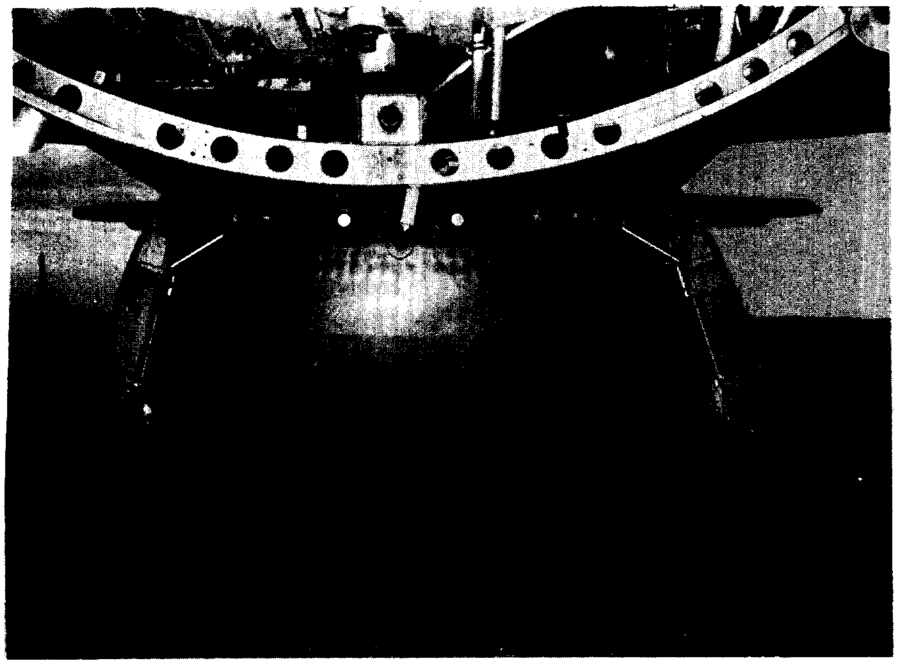

Fig. 10. Rubber Deicer Boot (Front View)

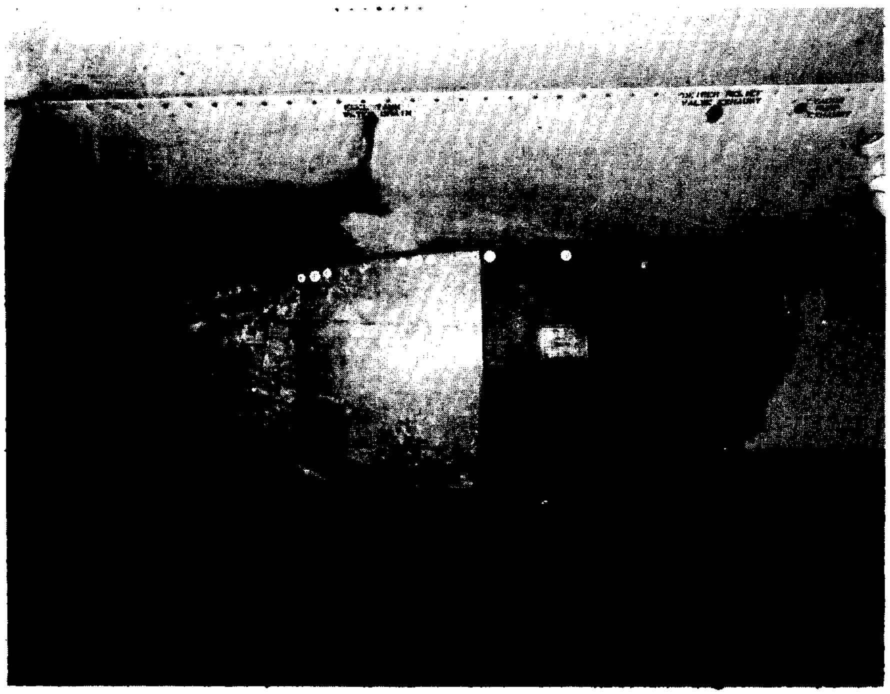

Fig. 11. Rubber Deicer Boot (Right Side View)

Results.

Laboratory tests made of a radome covered with a .110-inch thick boot section yielded efficiencies of 75% to 91% between 0° and 60° angles of incidence. With a .090-inch thick boot and for the same angles of incidence, efficiencies of 90% to 93% were noted. (See Fig. 12.)

Because of difficulties with the APQ/13 radar set, accurate comparisons of pictures taken under the different conditions could not be made. Fair comparisons among some of the pictures indicated a slight decrease in range with the boot in the deflated condition and an improvement with the boot inflated. However, degradation was so slight that the radar observer was unable to notice it on the scope. Frequency pulling varied between 2.2 and 4.8 megacycles. It may be said generally that the deicer boot which was tested offered little interference to electrical transmission and that the results were very gratifying.

Boot No. 2, with a total wall thickness of .090-inch was installed on Strategic Air Command B-29, No. 42-94071. Strategic Air Command will conduct its own series of tests to determine the ability of the boot to deice and to ascertain the effect of the boot on electrical transmission.

Because of a lack of active flight test time, Wright Air Development Center was unable to conduct a sufficient number of flight tests to prove the merits of the rubber boot. Consequently, although test results were obtained, these results were considered to be merely a good indication as to what might be expected but in nowise conclusive. The final decision rests with the Strategic Air Command, whose tests should offer definite and indisputable data on the value of the boot as an ice-prevention method.

SECTION V

CONCLUSIONS

The results of the tests conducted indicate that radome deicing can be accomplished effectively without serious effect on radar attenuation. The systems, which were developed, are adequate and can be installed quickly and without extensive modification to the aircraft.

Although chemical coatings (silicone oil in particular) hold very definite possibilities as anti-icing agents, none is recommended at present. Some work needs to be done to improve the resistance of silicone oil and other chemicals to erosion caused by rain and wind velocity. Under present conditions, it is doubtful whether a silicone oil could remain on a hard radome's surface for a sufficient length of time to prove effective as an anti-icing agent. It was

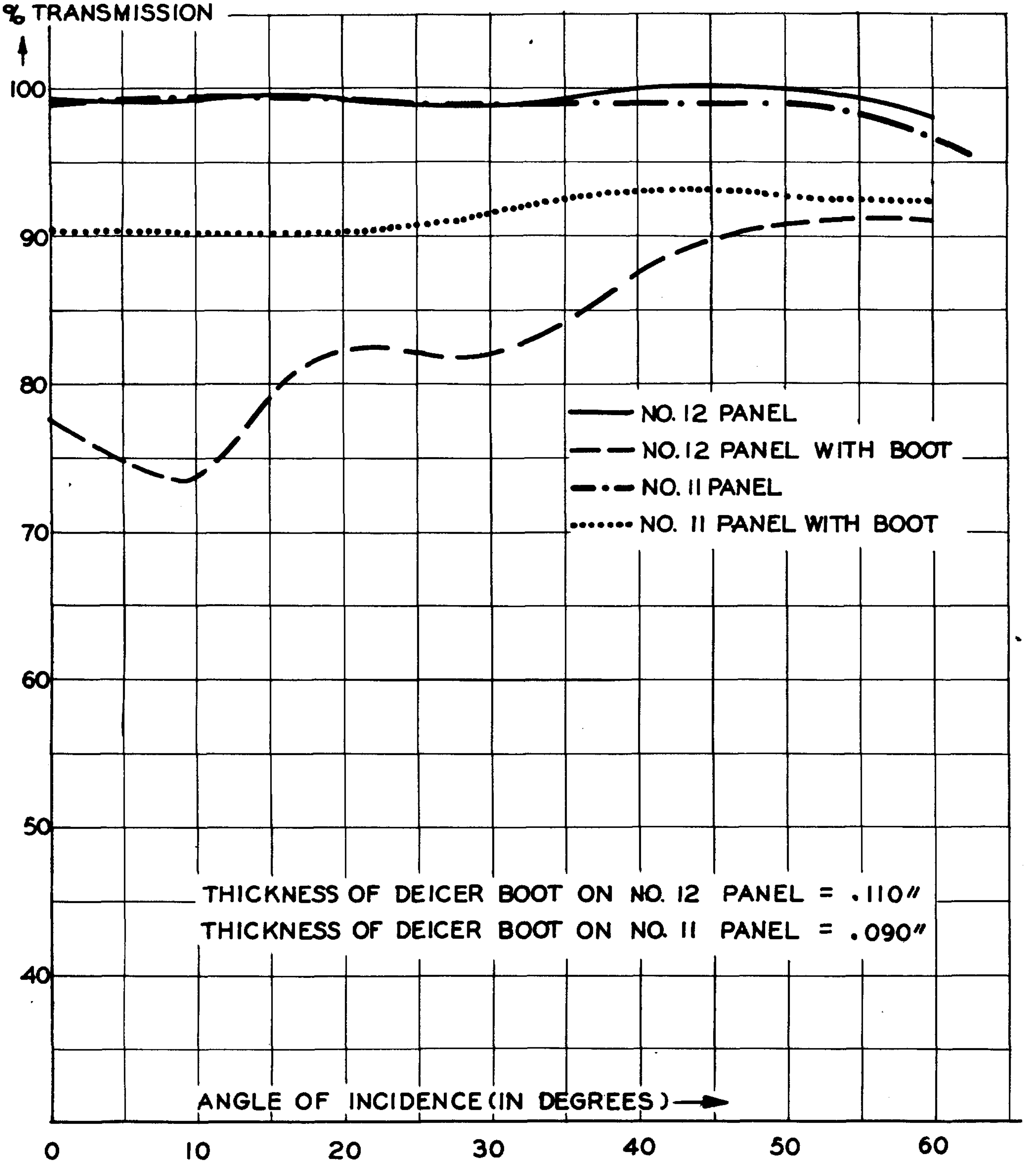

FIG. 12

ELECTRICAL TRANSMISSION
X-BAND PANELS, HONEYCOMB CORE

decided, therefore, to abandon chemical coatings as a possible solution.

A liquid spray system, using 60% ethylene glycol solution in water, can successfully deice a B-29 radome surface with no effect on radar attenuation. Being a mechanical system, it is subject to mechanical problems, and it is possible that the nozzles may become clogged. In a B-29, a fluid deicing system would add approximately 95 pounds of weight including 10 gallons of deicing solution. An 8-12 gph rate of flow is needed to accomplish satisfactory deicing. The flow of fluid does not seriously impair the electrical transmission properties of radar equipment.

A rubber boot is a positive means of deicing a radome and is subject to few mechanical problems. As an added safeguard, the boot should be coated with a fine layer of grade DC XF-126 (produced by Dow-Corning Chemical Co.) silicone oil as described in Section II of this report. This will facilitate the removal of ice from the boot.

Initial tests indicate that the deicer boot has little effect on electrical transmission, not enough to influence seriously the search characteristics of radar. Range, clarity, and details of picture on the scope retain original value as seen by visual observation. The addition of the rubber boot on the radome does not degrade the frequency stability of the AN/APQ-13 radar to any appreciable degree. However, with a thickness of .110 inch, the expected life of a boot is about 1-1 1/2 years, while with a .090-inch boot, a life of 7-9 months may be expected. Use of a rubber boot eliminates the need of a Neoprene coating for erosion resistance. A total weight of about 25 pounds is added.

Neither the boots nor the installation drawings have been assigned Air Force numbers as yet. The .090-inch boot is identified as Goodrich part No. 21-655-13-1; the .110-inch boot, as Goodrich part No. 21-655-14-1. Actual installation of the boots on the B-29 radome is covered in Goodrich Installation Drawing No. C-3054.

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